DECLARATION

In the matter of U.S. patent application No. 10/556,093 in the name of AICHI STEEL CORPORATION. and Vodafone K.K.

I, the undersigned, Yukie KOJO, of 1-2-16, Tennou, Ichinomiya-shi, Aichi 491-0046, Japan

sincerely declare as follows:

1. I am well acquainted with the English and Japanese languages and am competent to translate from Japanese into English.

2. I have executed with the best of my ability, a true and correct translation into the English language of the Japan priority application No. 2004-146831 with the filing date of 17 May 2004.

Dated, December 17, 2007

Signature: Yukie Kojo

[Name of Document] Patent Application

[Reference Number] SZ-85420

[Date of Submission] May 17, 2004

[Addressee] Commissioner of the Patent Office

[International Patent Classification] G01R 33/022

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[Amount of payment] 21,000 yen

[List of Appended Documents]

[Document] Description 1

[Document] Figures 1

[Document] Abstract 1

[ID Number of General Power of Attorney] 0008749

[CLAIMS]

[Claim 1] An attitude detection sensor comprising:

three magnetic sensing parts that detect magnetic field strength in respective directions along three axes substantially perpendicular to each other;

two tilt sensing parts that detect respective tilt angles around two axes substantially perpendicular to each other;

and an electronic circuit that controls the magnetic sensing parts and the tilt sensing parts;

wherein the three magnetic sensing parts, the two tilt sensing parts, and the electronic circuit are disposed on an IC substrate in the form of a module, and

wherein each tilt sensing part is composed of a magnet body that moves in accordance with the tilt angle and a magnetic detection head that detects a magnetic field originating from the magnet.

[Claim 2] An attitude detection sensor according to Claim 1, wherein each of the magnetic sensing parts and the magnetic detection heads is composed of a MI element comprising a magneto-sensitive element and a electro-magnetic coil wound around the magneto-sensitive element, the MI element configured to generate a electric potential difference between two ends of the electro-magnetic coil depending on a change in a current flowing through the magneto-sensitive element; and

wherein each tilt sensing part comprises a supporting post protruding from a surface of the IC substrate in a direction perpendicular to the surface of the IC substrate, and a cantilever one end of which is supported by the supporting post such that the cantilever can rotate around the supporting post along the surface of the IC substrate and on the other end of which the magnet body is disposed.

[Claim 3] An attitude detection sensor according to Claim 2,

wherein the magnet body is composed of a first magnet body magnetized in one direction and a second magnet body magnetized in an opposite direction.

[Claim 4] An attitude detection sensor according to Claim 2 or 3, wherein each of the magnetic sensing parts and the magnetic detection heads is configured to be able to detect magnetic field strength by detecting a induced voltage generated between two ends of the electro-magnetic coil thereof when the current flowing through the magneto-sensitive element rises up or falls down at a rate equal to or less than 10 nsec.

[Claim 5] An attitude detection sensor according to Claim 4, wherein the magnetic detection head detects a voltage induced between both end of the electro-magnetic coil when the current flowing through the magneto-sensitive element falls down.

[Claim 6] An attitude detection sensor according to any one of Claims 2 to 5, wherein the IC substrate comprises at least a first IC substrate on which a vertical magnetic sensing part for detecting the magnetic field strength in a direction perpendicular to the surface of the IC substrate, and a second IC substrate held on the first IC substrate,

the vertical magnetic sensing part is disposed, in parallel to the second IC substrate, on a surface of the first IC substrate.

[Claim 7] An attitude detection sensor according to any one of Claims 1 to 6, wherein the electronic circuit comprises a first electronic circuit that controls the magnetic sensing parts and a second electronic circuit that controls the tilt sensing parts, the first electronic circuit controlling the three magnetic sensing parts with time-sharing, and the second electronic circuit controlling the two tilt sensing parts with time-sharing.

[Claim 8] An attitude detection sensor according to any one of Claims 1 to 6, wherein the electronic circuit is configured

to control the three magnetic sensing parts and the two tilt sensing parts with time-sharing.

[Claim 9] An attitude detection sensor according to any one of Claims 3 to 8, wherein the electronic circuit corrects a measurement signal output from each magnet detection head by using at least one of the measurement signals output from the three magnetic sensing parts.

[Claim 10] An attitude detection sensor according to any one of Claims 1 to 9, wherein the attitude detection sensor is in the form of a surface mount chip.

[Claim 11] A portable telephone comprising:

an attitude detection sensor according to any one of Claims 1 to 10, a central processing unit, and a memory element for storing an operation program,

wherein the central processing unit is configured to download a signal output from each magnetic detection sensor and performs a predetermined operation in accordance with the operation program.

[Document] Specification

[Title of the Invention] Attitude Detection Sensor And Portable Telephone Using The Attitude Detection Sensor

[TECHNICAL FIELD]

[0001]

The present invention relates to an attitude detection sensor for detecting a bearing and a tilt and to a portable telephone using such an attitude detection sensor.

[BACKGROUND ART]

[0002]

An attitude detection sensor for detecting a bearing and a tilt is known, which is composed of a combination of a 3-axis magnetic sensing part and a 2- or more axis acceleration sensing part. More specifically, a magnetic sensing part using a Hall device and an acceleration sensing part including a strain gauge for detecting displacement of a weight which moves depending on a gravitational force applied to the weight (as disclosed, for example, in Patent Document 1).

[0003]

Patent Document 1: Japanese Unexamined Patent Application Publication No. 2003-172633

[0004]

However, the conventional attitude detection sensor has the following problems. In this attitude detection sensor, because the magnetic sensing part and the acceleration sensing part are based on different measurement principles, it is difficult to achieve an efficient disposition of these sensors, and thus it is difficult to achieve miniaturization of total size of an attitude detection sensor. Besides, the magnetic sensing part and the acceleration sensing part need completely different electrical circuits for processing signals output from these sensors. The necessity for two different types of

electrical circuits also makes it difficult for the attitude detection sensor to have a sufficiently small size.

[Disclosure of Invention]

[Problems to be Solved by the Invention]

[0005]

In view of the problems described above, the present invention provides a small-sized attitude detection sensor capable of detecting both a bearing and a tilt.

[Means for Solving the Problems]

[0006]

According to a first aspect of the present invention, an attitude detection sensor includes:

three magnetic sensing parts that detect magnetic field strength in respective directions along three axes substantially perpendicular to each other;

two tilt sensing parts that detect respective tilt angles around two axes substantially perpendicular to each other;

and an electronic circuit that controls the magnetic sensing parts and the tilt sensing parts;

wherein the three magnetic sensing parts, the two tilt sensing parts, and the electronic circuit are disposed on an IC substrate in the form of a module, and

wherein each tilt sensing part is composed of a magnet body that moves in accordance with the tilt angle and a magnetic detection head that detects a magnetic field originating from the magnet. (Claim 1)

[0007]

In this attitude detection sensor according to the first aspect, as described above, the three magnetic sensing parts that detect magnetic field strength in respective directions along three axes substantially perpendicular to each other, the two tilt sensing parts that detect respective tilt angles around

two axes substantially perpendicular to each other, and the electronic circuit that controls the magnetic sensing parts and the tilt sensing parts are disposed on the IC substrate in the form of the module.

[0008]

The two tilt sensing parts are capable of detecting the tilt angle of a plane defined by the two axes perpendicular to each other. The three magnetic sensing parts allow a detection of a rotation angle which rotates on its axis regardless of the tilt angle. Thus, the combination of a set of the two tilt sensing parts and a set of the three magnetic sensing parts makes it possible to detect the attitude and the bearing of the attitude detection sensor.

[0009]

In this attitude detection sensor, because the two tilt sensing parts and the three magnetic sensing parts are placed into the module, the attitude detection sensor has a smaller size and can control with smaller power consumption than a size and power consumption needed when the tilt sensing parts and the magnetic sensing parts are in the form of separate parts. The modularized attitude detection sensor is capable of maintaining high accuracy in terms of relative positions of axes of the tilt sensing parts and the magnetic sensing parts. This allows a further improvement in detection accuracy of the attitude and the bearing.

[0010]

As described above, the attitude detection sensor according to the first aspect of the present invention has the advantage that it has the small size, it can operate with small consumption power, and it can provide high axis accuracy.

[0011]

According to a second aspect of the present invention,

portable telephone includes:

an attitude detection sensor according to one of Claims 1 to 12, a central processing unit, and a memory element for storing an operation program,

wherein the central processing unit is configured to download a signal output from each magnetic detection sensor and performs a predetermined operation in accordance with the operation program.(Claim 11)

[0012]

The portable telephone according to the second aspect of the present invention is capable of accurately detecting the attitude and the bearing of the portable telephone by using the attitude detection sensor disposed in the portable telephone. The central processing unit in the portable telephone acquires signal output of the magnetic detection sensors, that is, the information such as the attitude and the bearing or the like of the portable telephone and performs the predetermined operation in accordance with the operation program.

[0013]

A specific example of the predetermined operation is scrolling of a screen in a particular direction in accordance with the attitude information. Another example is moving of a cursor in a particular direction in accordance with the attitude information. A still another example of the predetermined operation is to start or end a telephone call or open a received mail, when a particular change occurs in the attitude, for example, when the portable telephone is rotated or shaken.

[0014]

Composing the portable telephone to perform a particular operation depending on a signal output of the attitude detection sensor, the attitude information can be used as input information of the portable telephone without using keys or input information

of the portable telephone concerting key operation.

Further, as the above particular operation, for example, the output signal of the attitude detection sensor is stored in the memory element such as a RAM or a ROM. In this case, based on the time-dependent change of the output signal stored in the memory element, it is possible to realize the motion of a user of the portable telephone.

[Best Mode for Carrying Out the Invention]

[0015]

The attitude detection sensor according to the first aspect of the present invention is applicable for controlling a portable device such as a portable telephone and also other various devices such as a car, an autonomous mobile robot, a manipulator of a robot, etc.

[0016]

It is preferable that each of the magnetic sensing parts and the magnetic detection heads is composed of a MI element comprising a magneto-sensitive element and a electro-magnetic coil wound around the magneto-sensitive element, the MI element configured to generate a electric potential difference between two ends of the electro-magnetic coil depending on a change in a current flowing through the magneto-sensitive element; and

wherein each tilt sensing part comprises a supporting post protruding from a surface of the IC substrate in a direction perpendicular to the surface of the IC substrate, and a cantilever one end of which is supported by the supporting post such that the cantilever can rotate around the supporting post along the surface of the IC substrate and on the other end of which the magnet body is disposed. Preferably, the tilt sensing part includes a supporting post protruding from a surface of an IC substrate in a direction perpendicular to the surface of the IC substrate, and also includes a cantilever one end of which

is supported by the supporting post such that the cantilever can rotate around the supporting post along the surface of the IC substrate and on the other end of which the magnet body is disposed.(Claim 2)

[0017]

The effect that a voltage depending on a change in a current flowing through a magneto-sensitive element is induced in a electro-magnetic coil is called MI effect. The MI effect can occur in a magneto-sensitive element composed of a magnetic material in which electron spins are aligned in a rotational direction around a direction that a supplied current flows. If the current flowing through the magneto-sensitive element is changed abruptly, an abrupt change in the magnetic field in the rotational direction occurs, which causes a change in the electron spin direction depending on an ambient magnetic field. The change in the electron spin direction causes a change in internal magnetization and a change in impedance of the magneto-sensitive element.

[0018]

The operation of the MI element is based on the effect of the magneto-sensitive element composed of the magnetic material in which electron spins are aligned in the rotational direction around the direction in which the supplied current flows. If the current flowing through the magneto-sensitive element is changed abruptly, an abrupt change in the magnetic field in the rotational direction occurs, which causes a change in the electron spin direction depending on an ambient magnetic field. The change in the internal magnetization or the impedance of the magneto-sensitive element is converted into a voltage generated across the magneto-sensitive element itself or generated between two ends of a magneto coil wound around the magneto-sensitive element or is converted into a current flowing

through the magneto-sensitive element itself or flowing through the magneto coil wound around the magneto-sensitive element. A sensor produced by combining a MI element and an electronic circuit is called an MI sensor.

[0019]

A high-sensitivity magnetic sensing part or magnetic detection head can be obtained, by using the MI element that generates a electric potential difference between two ends of the electro-magnetic coil depending on the change in the current flowing through the magneto-sensitive element. Such a magnetic sensing part or a magnetic detection head is capable of detecting displacement of the magnet body with high accuracy. The magneto-sensitive element may be in the form of a wire or a thin film. Specific examples of materials of the magneto-sensitive element include FeCoSiB and NiFe.

[0020]

Each magnetic sensing part using a MI element is capable of detecting magnetic field strength in a direction along each axis with high accuracy. The magnetic detection head using a MI element in each tilt sensing part is capable of accurately detecting the tilt angle of the IC substrate, that is, the rotation angle around the axis in the longitudinal direction of the cantilever.

[0021]

It is preferable that the magnet body is composed of a first magnet body magnetized in one direction and a second magnet body magnetized in an opposite direction.(Claim 3)

In this case, the first magnet body and the second magnet body have opposite magnetic moments in direction. Therefore, when an ambient magnetic field is applied to the first and second magnet bodies having opposite magnet moments, torques act on the first and second magnet bodies in opposite directions. The

torque acting on the first magnet body tries to move the cantilever in one direction, while the torque acting on the second magnet body tries to move the cantilever in the opposite direction, and thus torques are cancelled out. As a result, the displacement of the magnet body and the displacement of the cantilever due to the ambient magnetic field are suppressed.

[0022]

It is preferable that each of the magnetic sensing parts and the magnetic detection heads is configured to be able to detect magnetic field strength by detecting a induced voltage generated between two ends of the electro-magnetic coil thereof when the current flowing through the magneto-sensitive element rises up or falls down at a rate equal to or less than 10 nsec.(Claim 4)

[0023]

Such an abrupt change in the flowing current causes the magnetic field in the rotational direction around the magneto-sensitive element to change at a high rate corresponding to a velocity at which the change in the electron spin propagates, and thus a sufficiently high MI effect can be obtained. When the flowing current is risen or fallen at a rate equal to or less than 10 nsec, the magneto-sensitive element receives a current change of flow including a high-frequency component of about 0.1 GHz. By detecting the voltage induced at both ends of the electro-magnetic coil, it is possible to detect a change in internal magnetization depending on an ambient magnetic field as the size of the induced voltage, and thus it is possible to detect the strength of the ambient magnetic field with very high accuracy. The rising or the falling of the flowing current is defined by changing the current flowing through the magneto-impedance element from 10% to 90% or from 90% to 10% of the steady-state current, for example.

[0024]

It is preferable that the magnetic detection head detects a voltage induced between both end of the electro-magnetic coil when the current flowing through the magneto-sensitive element falls down. (Claim 5)

Better linearity concerning the magnetic field strength vs. output signal of the magnetic detection head is obtained in the case in which the induced voltage is detected when the flowing current falls down abruptly than in the case in which the induced voltage is detected when the flowing current rises up.

[0025]

It is preferable that the IC substrate comprises at least a first IC substrate on which a vertical magnetic sensing part for detecting the magnetic field strength in a direction perpendicular to the surface of the IC substrate, and a second IC substrate held on the first IC substrate,

the vertical magnetic sensing part is disposed, in parallel to the second IC substrate, on a surface of the first IC substrate. (Claim 6)

On the mounting surface of the first IC substrate, disposing the vertical magnetic sensing part in parallel to the second IC substrate means that the vertical magnetic sensing part is disposed on an area where the mounting height is not restricted by the second IC substrate.

[0026]

By mounting the vertical magnetic sensing part with a large height in parallel to the second IC substrate on the mounting surface of the first IC substrate, it becomes possible to make full use of space in the vertical direction of the attitude detection sensor. Thus, the attitude detection sensor is constructed in a form in which parts are disposed very densely.

[0027]

It is preferable that the electronic circuit includes a first electronic circuit that controls the magnetic sensing parts and a second electronic circuit that controls the tilt sensing parts, the first electronic circuit controlling the three magnetic sensing parts with time-sharing, and the second electronic circuit controlling the two tilt sensing parts with time-sharing. (Claim 7)

[0028]

In this case, because the first electronic circuit is shared by the three magnetic sensing parts, and the second electronic circuit is shared by the two tilt sensing parts, and thus a reduction in the total size of the attitude detection sensor and a reduction in power consumption are achieved. This allows an improvement in mountability of the attitude detection sensor on an electronic circuit board.

[0029]

It is preferable that the electronic circuit is configured to control the three magnetic sensing parts and the two tilt sensing parts with time-sharing. (Claim 8)

In this case, because the electronic circuit controls magneto-impedance elements of all magnetic sensing parts and tilt sensing parts by means of time-sharing, a further reduction in the size and simplification of the electronic circuit can be achieved.

[0030]

It is preferable that the electronic circuit corrects a measurement signal output from each magnet detection head by using at least one of the measurement signals output from the three magnetic sensing parts. (Claim 9)

By using the detection signal output from the magnetic sensing part, it becomes possible to eliminate an influence of

an ambient magnetic field such as geomagnetism on the detection signal of the tilt sensing part, and thus it becomes possible to greatly improve the measurement accuracy.

It is preferable that the attitude detection sensor is in the form of a surface mount chip.(Claim 10)

This allows a further improvement in mountability of the attitude detection sensor on an electronic circuit board or the like.

[EXAMPLES]

[0031]

(Example 1)

In Example 1, the invention is applied to a small-sized and low-power attitude detection sensor. The details of Example 1 are described below with reference to Figs. 1 to 10.

The attitude detection sensor of Example 1 includes, as shown in Fig. 1, three magnetic sensing parts 41 to 43 which detect magnetic field strength in directions along three axes substantially perpendicular to each other, two tilt sensing parts 2a and 2b which detect a tilt angle around each of two axes substantially perpendicular to each other, and an electronic circuit which controls the magnetic sensing parts 41 to 43 and the tilt sensing parts 2a and 2b, wherein these parts are disposed on an IC substrate 10 into the form of a module.

Each of the tilt sensing parts 2a and 2b is composed of a magnet body 21 and a magnetic detection head 23. Each magnet body 21 moves according to a tilt angle. Each magnetic detection head 23 detects a magnetic field emanating from the magnet body 21.

The structure of the tilt sensing parts 2a and 2b is described in further detail below.

[0032]

The tilt sensing parts 2a and 2b in the attitude detection

sensor 1 are disposed, as shown in Fig. 1, such that each tilt sensing part detects the tilt angle with respect to a corresponding one of two substantially perpendicular axes along two sides of the IC substrate 10 having a substantially rectangular shape. The magnetic sensing parts 41 to 43 are disposed such that each of two magnetic sensing parts detects a magnetic field strength along each of two substantially perpendicular sides of the IC substrate 10 having the substantially rectangular shape and the remaining magnetic sensing part detects a magnetic field strength along an axis (the vertical line of the IC substrate 10) perpendicular to the former two axes. An IC chip 14 for the magnetic sensing parts and an IC chip 12 for the tilt sensing parts are disposed on the surface of IC substrate 10. In the following explanation, axes along two substantially perpendicular sides of the IC substrate 10 are respectively referred to as an X axis 10a and a Y axis 10b, and the axis along the vertical line of the IC substrate 10 is referred to as a Z axis 10c.

[0033]

In each of the magnetic sensing parts 41 to 43, an amorphous wire with a length of 1 mm and a diameter of 20 mm (hereinafter, referred to simply as an amorphous wire 44) is used as a magneto-sensitive element 44. Each of the magnetic sensing parts 41 to 43 is formed, as shown in Figs. 2 and 3, such that a electro-magnetic coil 45 with an inner diameter equal to or less than 200 mm is wound around the periphery of an insulating resin tube 46 in which the amorphous wire 44 is inserted.

[0034]

That is, the operation of magnetic sensing parts 41 to 43 is based on the MI (Magneto-impedance) effect of the amorphous wire 44 serving as the magneto-sensitive element whose impedance greatly varies depending on the strength of the ambient magnetic

field in which the amorphous wire 44 is placed. This effect of the amorphous wire 44 is called magneto-impedance effect (MI). In these magnetic sensing parts 41 to 43, the strength of the magnetic field is detected by detecting a voltage induced when a pulse current is passed through the amorphous wire 44.

[0035]

MI effect is obtained in the magneto-sensitive element composed of a magnetic material in which electron spins are aligned in a rotational direction around a direction in which a supplied current flows. If the current passed through the magneto-sensitive element is changed abruptly, the magnetic field in the rotational direction around the current changes abruptly. The change in the magnetic field in the rotational direction causes a change in the direction of electron spins corresponding the ambient magnetic field, which causes a change in internal magnetization and a change in impedance because of the effect of MI.

[0036]

MI elements (magnetic sensing parts 41 to 43 in the present invention) using the MI effect is composed of a change such as internal magnetization and impedance of the magneto-sensitive element resulting from a change in electron spin direction caused by an abrupt change in a current flowing through the amorphous wire 44 serving as the magneto-sensitive element being converted to a voltage (induced voltage) between the both ends of the electro-magnetic coil 45 wound around the amorphous wire 44. Each of magnetic sensing parts 41 to 43 of this example has a magnetic detection sensitivity in a longitudinal direction of the amorphous wire 44 serving as the magneto-sensitive element.

[0037]

As shown in Figs. 4 and 5, each of magnetic sensing parts 41 to 43 is formed on an element substrate 47 having a groove-shaped

recess 470 that is 5 to 200 mm in depth and substantially rectangular in cross section. On each of side walls 470a facing each other in the inside of the recess 470, conductive patterns 45a extending in a direction substantially perpendicular to the direction of the groove are formed at substantially equal intervals. On the bottom surface 470b of the recess 470, conductive patterns 45b electrically connecting to conductive patterns 45a which position are shifted by one interval on the opposing side wall 470a are formed diagonally in regard to the groove direction.

[0038]

The amorphous wire 44 serving as the magneto-sensitive element is embedded in an insulating epoxy resin 46 (shown in Fig. 3 but not shown in Fig. 5) filled in the inside of the recess 470 having the conductive patterns 45a and 45b formed on the side walls 470a and the bottom surface 470b. Conductive patterns 45c extending in a direction substantially perpendicular to the groove direction are formed on the outer surface of the insulating resin 46 filled in the recess 470 such that each conductive pattern 45a on one side wall 470a is electrically connected to a conductive pattern 45a at a corresponding position on the opposing side wall 470a via one of conductive patterns 45c. The conductive patterns 45a, 45b, and 45c as a whole form a spiral electro-magnetic coil 45.

[0039]

In the present example, the conductive patterns 45a and 45b are formed by depositing a conductive thin metal film (not shown in the figure) over the entire inner surfaces 470a and 470b of the recess 470 and then patterning the deposited thin metal film by means of etching. The conductive patterns 45c are formed by evaporating a conductive thin metal film (not shown in the figure) on the surface of the insulating resin 46 and

then etching the conductive thin metal film.

[0040]

The effective inner diameter of the electro-magnetic coil 45 is 66 mm corresponding to the inner diameter of a circle having the same area as the area of the cross section of the recess 470. The turn-to-turn distance of the electro-magnetic coil 45 is equal to 50 mm. The magnetic sensing parts 41 to 43 are all formed according to the same specifications, and they are disposed such that the longitudinal directions of amorphous wires 44 of magnetic sensing parts 41 to 43 are parallel to the X axis 10a, the Y axis 10b, and the Z axis 10c, respectively.

[0041]

The IC chip 14 for controlling the magnetic sensing parts 41 to 43 has an electronic circuit including, as shown in Fig. 6, a signal generator 141 that generates a pulse current input to the amorphous wire 44 and a signal processor 142 that outputs a measurement signal according to the induced voltage e (Fig. 7(b)) of electro-magnetic coil 45. The signal generator 141 generates a pulse current with a width of 40 nsec at intervals of 5 msec. The signal generator 141 of this example also outputs a trigger signal in synchronization with a falling edge of each pulse current to an analog switch 142a of the signal processor 141.

[0042]

The signal processor 142 is composed of combination of a synchronous detector circuit which functions as a so-called "peak hold" circuit and an amplifier 142b. The synchronous detector circuit includes an analog switch 142a which turns on and off the electric connection between the electro-magnetic coil 45 and the signal processor 142 in synchronization with the trigger signal and also includes a capacitor 142c connected to the electro-magnetic coil 45 via the analog switch 142a.

[0043]

A method of detecting a magnetic field using the magnetic sensing parts 41 to 43 is briefly described below. In this magnetic field detection method, as shown in Fig. 7, when the pulse current passed through the amorphous wire 44 falls down (Fig. 7(a)), the induced voltage e (Fig. 7(b)) generated in the electro-magnetic coil 45 is measured. In the present example, the turn-off time, defined by a time needed for the pulse current to fall down from 90% of the steady-state value (150 mA) to 10% of the steady-state value, is set to be equal to 4 nsec.

[0044]

That is, as shown in Fig. 7, at the moment when the pulse current flowing through the amorphous wire 44 placed into the magnetic field is turned off, an induced voltage e with a magnitude proportional to a magnetic field component in the longitudinal direction of the amorphous wire 44 is generated between the two ends of the electro-magnetic coil 45. In the IC chip 14 of this example, the induced voltage e between the electro-magnetic coil 45 is stored in the capacitor 142c via the analog switch 142a turned on by the trigger signal, is amplified by the amplifier 142b, and is output via an output terminal 145. As described above, each of the magnetic sensing parts 41 to 43 outputs, via the IC chip 14, a signal corresponding to the intensity of the magnetic field component in the longitudinal direction of the amorphous wire 44.

[0045]

The IC chip 14 for controlling the magnetic sensing parts has, as shown in Fig. 8, an electronic switch 148 for switching an electrical connection of the signal generator 141 to the magneto-sensitive elements 44 of the respective magnetic sensing parts 41 to 43 and also switching an electrical connection of the signal processor 142 to the electro-magnetic coils 45.

Herewith, the three magnetic sensing parts 41 to 43 which measure the intensity of the magnetic field components along the X axis 10a, the Y axis 10b, and the Z axis 10c (Fig. 1) are allowed the IC chip 14 to be time-shared for the three magnetic sensing parts 41 to 43.

[0046]

Each of the tilt sensing parts 2a and 2b includes, as shown in Fig. 1, a cantilever 22 having a magnet body 21 disposed on the free end of the cantilever 22 and a magnetic detection head 23 which detects the strength of a magnetic field generated by the magnet body 21. In the tilt sensing parts 2a and 2b, the gravitational force applied to the cantilever 22 varies depending on the tilt angle, and thus the magnet body 21 disposed on the free end of each cantilever 22 is displaced depending on the tilt angle. A change in magnetic field strength caused by the displacement of the magnet body 21 is detected by the magnetic detection head 23.

[0047]

Each cantilever 22 is made of an elastic material and one end thereof in the longitudinal direction is supported by the supporting post 28 protruding from the surface of the IC substrate 10 in a direction perpendicular to the surface of the IC substrate 10. The magnet body 21 is disposed on the free end opposite to the end supported by the supporting post 28. The cantilever 22 is made of a NiP material in the form of a substantially rectangular plate with a width of 0.3 mm, a length of 1.5 mm, and a thickness of 5 mm. Furthermore, in the present example, each cantilever 22 has an elongated hole 220 with a width of 0.22 mm extending from a position at which the cantilever 22 is connected to the supporting post 28 to a position 0.38 mm before the free end so that the hole 220 causes a reduction in stiffness against force in a thickness direction of the

cantilever 22 and thus the magnet body 21 is displaced more widely.

[0048]

In the present example, the elongated hole 220 causes the cantilever 22 to have a character frequency in the range from 50 Hz to 60 Hz. Although in the present example, the elongated hole 220 is formed on side of the cantilever, the cantilever may be used in the form of a flat plate having no hole.

[0049]

The magnet body 21 is disposed on a side of the cantilever 22, at the free end of the cantilever 22. In the present example, the magnet body 21 is formed by coating a magnetic material on the side of the cantilever 22, drying and hardening the magnetic material, and finally magnetizing the magnetic material. In the present example, as shown in Fig. 9(a), a first magnet body 21a whose north pole is located on the outer side and a second magnet body 21b whose south pole is located on the outer side are disposed at positions adjacent in the longitudinal direction of the cantilever 22. That is, the first magnet body 21a and the second magnet body 21b are opposite in magnetization direction M and thus opposite in magnetic moment.

[0050]

Thus, when the magnet body 21 is placed in a magnetic field, torques are applied to the first magnet body 21a and the second magnet body 21b in opposite directions. As a result, the magnet bodies 21a and 21b try to turn the cantilever 22 in opposite directions. Thus, as a whole of the magnet body 21, the torques caused by an ambient magnetic field are compensated, and displacement caused by the ambient magnetic field is suppressed. This minimizes an error in measured tilt angle caused by displacement of the magnet body 21 caused by an ambient magnetic field such as geomagnetism. Note that the magnet body 21 may be composed of only a single magnet.

[0051]

In the above-described magnet body 21, as shown in Fig. 9(a), a magnetic field in the form of a closed loop is created as a composition of a magnetic field generated by the first magnet body 21a and a magnetic field generated by the second magnet body 21b. On the other hand, in a case in which only a single magnet body is disposed as shown in Fig. 9(b), the magnet body generates a magnetic field in the form of an open loop and the magnetic field is leaked surrounding, and thus it can cause electromagnetic noise and the like.

That is, in the tilt sensing parts 2a and 2b (Fig. 1) of the present example, the magnet body 21 is constructed in the form that minimizes the influence of leakage of the magnetic field on the surrounding, thereby preventing an ambient circuit from receiving electromagnetic noise. In the present example, each of the magnet bodies 21a and 21b has a width W (the size measured in the longitudinal direction of the cantilever 22) of 0.5 mm, a height of 0.3 mm, and a thickness T of 100 mm.

[0052]

The magnetic detection head 23 of each of tilt sensing parts 2a and 2b may be disposed such that the magneto-sensitive element 24 is substantially perpendicular to the magnetic field generated by the magnet body 21 or may be disposed such that the magneto-sensitive element 24 is parallel to the magnetic field generated by the magnet body 21. Alternatively, the magneto-sensitive element 24 may be disposed such that it is oriented in an arbitrary direction with respect to the magnetic field. However, in this case, the output value of the magnetic detection head 23 does not have a maximum or minimum value when the cantilever 22 is in its initial position, and thus it is required to shift the output value of the magnetic detection head 23.

[0053]

The magnetic detection heads 23 (Fig. 1) of the respective tilt sensing parts 2a and 2b are formed according to the same specifications as those for the magnetic sensing parts 41 to 43. That is, in the present example, the high-sensitivity magnetic detection head 23 of each of the tilt sensing parts 2a and 2b is realized by a combination of the amorphous wire 24 (Fig. 10) serving as the magneto-sensitive element and the electro-magnetic coil 25 (Fig. 10), as with the magnetic sensing parts 41 to 43.

[0054]

As shown in Fig. 10, the IC chip 12 for controlling the tilt sensing parts is basically similar to the IC chip 14 (Fig. 8) for controlling the magnetic sensing parts. That is, the IC chip 12 has an electronic circuit including, a signal generator 121 that generates a pulse current input to the amorphous wire 24 and a signal processor 122 that outputs a measurement signal according to the induced voltage generated in the electro-magnetic coil 25.

[0055]

The IC chip 12 for controlling the tilt sensing parts has an electronic switch 128 for switching an electrical connection of the signal generator 121 to the magneto-sensitive elements 24 of the respective tilt sensing parts 2a and 2b and also switching an electrical connection of the signal processor 122 to the electro-magnetic coils 25. Two tilt sensing parts 2a and 2b are allowed the IC chip 12 to be time-shared for the two tilt sensing part 2a and 2b. The magnetic detection head 23 of each of the tilt sensing parts 2a and 2b detects a magnetic field in a similar manner to the magnetic sensing parts 41 to 43 described above, and thus a duplicated description thereof is omitted.

[0056]

In the present example, as described above, the attitude detection sensor 1 is composed of the tilt sensing parts 2a and 2b and the magnetic sensing part 41 to 43, which are integrated in a single module. In this attitude detection sensor 1, the IC chip 12 (Fig. 12) serving as an electrical control circuit is shared by the two tilt sensing parts 2a and 2b, and the IC chip 14 (Fig. 8) serving as another electrical control circuit is shared by the three tilt sensing parts 41 to 43, and thus the attitude detection sensor 1 has a small size and can operate with small power consumption.

[0057]

In the tilt sensing parts 2a and 2b, the first magnet body 21a and the second magnet body 21b, which are opposite in the magnetization direction M (Fig. 9), are disposed at positions adjacent in the longitudinal direction of the cantilever 22. Thus, the magnet body 21 composed of the combination of the first and second magnet bodies 21a and 21b receives a very small a torque caused by an ambient magnetic field such as geomagnetism. This allows the attitude detection sensor 1 of the present example to detect a tilt angle with very high accuracy.

[0058]

Furthermore, because the magnet body 21 is composed of the combination of the first and second magnet bodies 21a and 21b which are located at adjacent positions as described above, the magnetic field emanating from the magnet body 21 is in the form of a closed loop. Therefore, the attitude detection sensor 1 using the magnet body 21 generates very low electromagnetic wave noise, and thus the attitude detection sensor 1 can be mounted on an electronic board on which many other electronic parts are mounted at locations close to each, without exerting a significant influence on other electronic parts.

[0059]

As described above, the magnetic detection heads 23 and the magnetic sensing parts 41 to 43 are formed according to the same specifications. Besides, the magnetic detection head 23 of the tilt sensing part 2a and the magnetic sensing part 42 are placed such that the amorphous wires 44 thereof extend in the same direction, and the magnetic detection head 23 of the tilt sensing part 2b and the magnetic sensing part 41 are placed such that the amorphous wires 44 thereof extend in the same direction.

[0060]

The voltage induced by an ambient magnetic field such as geomagnetism is substantially equal to the voltage induced by the ambient magnetic field in the electro-magnetic coil 25,45 wound around the amorphous wire 44, when the amorphous wires 44 extend in the same longitudinal direction. Thus, when the correction in which the signal output of the magnetic sensing part 42 subtracted from the signal output of the magnetic detection head 23 of the tilt sensing part 2a is conducted, the influence by the ambient magnetic field is excluded from the signal output of the tilt sensing part 2a, and thus the detection accuracy is improved. By the way, the tilt sensing part 2b is similar.

[0061]

In the present example, as described above, the specifications are the same for the magnetic detection heads 23 and the magnetic sensing parts 41 to 43, and the electric circuit of the IC chip 14 for use with the magnetic sensing parts is basically similar to the electric circuit of the IC chip 12 for use with the tilt sensing parts. Therefore, a single control circuit may be used to control all magnetic sensing parts 41 to 43 and tilt sensing parts 2a and 2b by time-sharing the single control circuit. For example, the single control circuit for

the above purpose may be obtained by replacing the electronic switch 148 of the IC chip 14 or the electronic switch 128 of the IC chip 12 with a 5-channel electronic switch.

[0062]

(Example 2)

In Example 2, the attitude detection sensor of Example 1 is modified such that the IC substrate is composed of two substrates. The details of the attitude detection sensor in Example 2 are described below with reference to Figs. 11 and 12.

In the present example, the IC substrate 10 includes a first IC substrate 101 and a second IC substrate 102. Of three magnetic sensing parts 41 to 43, at least a vertical magnetic sensing part 43 for detecting the magnetic field strength in the vertical direction (the Z direction denoted by an arrow 10C in Fig. 1) to the IC substrate 10 is disposed on the first IC substrate 101. The second IC substrate 102 is held on the first IC substrate 101. The vertical magnetic sensing part 43 is disposed on a surface, which faces the second IC substrate 102, of the first IC substrate 101, in an area which is not in contact with the second IC substrate 102. Furthermore, in the attitude detection sensor 1 of the present example, the tilt sensing parts 2a and 2b, which are greater in height than the magnetic sensing parts 41 and 42 and the IC chips 12 and 14, are also disposed on the surface, which faces the second IC substrate 102, of the first IC substrate 101, in the area which is not in contact with the second IC substrate 102.

[0063]

In the present example, the second IC substrate 102 is a double-sided substrate having two through-holes 105. On a first mounting surface 102a, which faces the first IC substrate 101, of the second IC substrate 102, two magnetic sensing parts

41 and 42 are mounted, which detect the strength of a magnetic field in respective directions along two axes parallel to the first mounting surface 102a and perpendicular to each other, and the IC element 12 is also mounted, which controls the magnetic sensing parts 41 to 43. The IC element 12 for controlling the tilt sensing parts 2a and 2b are mounted on a second mounting face 102b, opposite to the first mounting surface 102a, of the second IC substrate 102.

[0064]

As described above, in the attitude detection sensor 1 of the present example, the IC substrate 10 has a two-level structure including the first IC substrate 101 and the second IC substrate 102, and parts with large heights (such as the vertical magnetic sensing part 43 and the tilt sensing parts 2a and 2b) are disposed in the area where there is no overlap in the vertical direction between the IC substrates 101 and 102. Thus, the attitude detection sensor 1 of the present example is constructed in the form of a module in which parts are disposed very densely.

The attitude detection sensor 1 of to the present example is similar to the attitude detection sensor 1 in Example 1, in terms of the structure, the operation, and the advantages, except for the difference described above.

[0065]

(Example 3)

In Example 3, the invention is applied to a portable telephone using an attitude detection sensor in Example 1 or Example 2. The details of Example 3 are described below with reference to Fig. 13.

A portable telephone 6 is designed to perform two-way voice communication by means of radio transmission. The portable telephone 6 includes an attitude detection sensor 1, a one-chip

microcomputer 62 including a CPU (Central Processing Unit), and a memory element (not shown in the figure) in which an operation program is stored, wherein the attitude detection sensor 1, the one-chip microcomputer 62, and the memory element are mounted on an internal substrate 65. The attitude detection sensor 1 detects rotation angles around an X axis, a Y axis, and a Z axis, respectively, which are defined on the portable telephone 6, that is, a rolling angle, a pitch angle, and a yaw angle. The detected rotation angles are output to the microcomputer 62. In the present example, the attitude detection sensor 1 has a very small size. More specifically, for example, the attitude detection sensor 1 has a width of 5.5 mm, a depth of 5.5 mm, and a height of 1.5 mm.

[0066]

The portable telephone 6 is capable of serving as an Internet browser, which allows various kinds of information received via the Internet to be displayed on a liquid crystal display screen 61. If the portable telephone 6 is tilted, the content displayed on the liquid crystal display screen 61 is scrolled in a tilted direction. More specifically, in accordance with the operation program stored in the memory element, the microcomputer 62 calculates the amount of scrolling to be performed on the content displayed on the liquid crystal display screen 61 depending on the attitude information output from the attitude detection sensor 1.

Thus, according to the portable telephone 6 of the present example, the attitude-sensitive operation assists the operation using operation buttons 630 disposed on an operation control panel 63. This allows a user to easily operate the portable telephone 6.

The present example is similar to Example 1 or Example 2, in terms of the structure, the operation, and the advantages,

except for the difference described above.

[Brief Description of the Drawings]

[0067]

[Fig. 1] Fig. 1 is a perspective view of an attitude detection sensor in Example 1.

[Fig. 2] Fig. 2 is a front view of a magnetic sensing part in Example 1.

[Fig. 3] Fig. 3 is a cross-sectional view of cross-sectional structure of a magnetic sensing part in Example 1.

[Fig. 4] Fig. 4 is a perspective view for explaining a magnetic sensing part in Example 1.

[Fig. 5] Fig. 5 is a perspective view for explaining a electro-magnetic coil in Example 1.

[Fig. 6] Fig. 6 is an equivalent circuit diagram showing a electric circuit of an IC chip for use in a magnetic sensing part in Example 1.

[Fig. 7] Fig. 7 is a graph showing the relationship between a pulse current passed through an amorphous wire and a voltage induced in a electro-magnetic coil in Example 1.

[Fig. 8] Fig. 8 is a circuit diagram showing a electric circuit of an IC chip for use in a magnetic sensing part in Example 1.

[Fig. 9] Fig. 9 is a top view showing a magnet body and associated parts in a tilt sensing part in Example 1.

[Fig. 10] Fig. 10 is a circuit diagram showing a electric circuit of an IC chip for use in a tilt sensing part in Example 1.

[Fig. 11] Fig. 11 is a top view of an attitude detection sensor in Example 2.

[Fig. 12] Fig. 12 is a cross-sectional view (taken along a line A-A of Fig. 11) showing a cross-sectional structure of

an attitude detection sensor in Example 2.

[Fig. 13] Fig. 13 is a partially cutaway perspective view of a portable telephone in Example 3.

[EXPLANATION OF LETTERS OR NUMERALS]

[0068]

1 ... attitude detection sensor

10 ... IC substrate

12,14 ... IC chip

2a,2b ... tilt sensing part

21 ... magnet body

22 ... cantilever

23 ... magnetic detection head

24 ... supporting post

41,42,43 ... magnetic sensing part

24,44 ... amorphous wire

25,45 ... electro-magnetic coil

[DOCUMENT] ABSTRACT

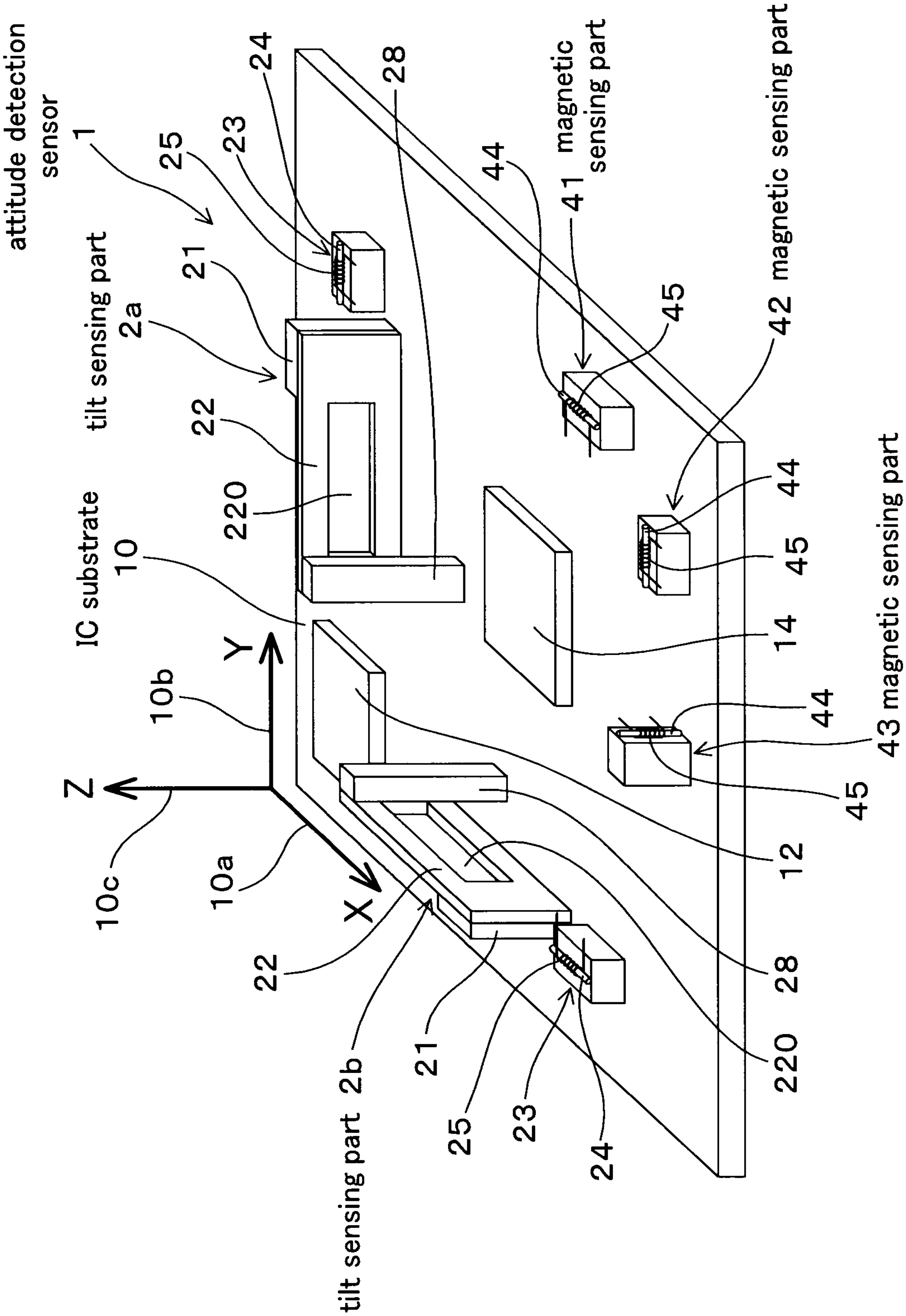
[ABSTRACT]

[PROBLEM] The present invention aims to offer a portable telephone using an attitude detection sensor and to offer the attitude detection sensor which has the small size, it can operate with small consumption power.

[MEANS FOR SOLVING THE PROBLEMS] An attitude detection sensor 1 comprises three magnetic sensing parts 41 to 43 which detect magnetic field strength in directions along three axes substantially perpendicular to each other, two tilt sensing parts 2a and 2b which detect a tilt angle around each of two axes substantially perpendicular to each other, and an electronic circuit which controls the magnetic sensing parts 41 to 43 and the tilt sensing parts 2a and 2b. The three magnetic sensing parts 41 to 43, the two tilt sensing parts 2a and 2b, and the electronic circuit are disposed on an IC substrate 10 in the form of a module.

[REPRESENTATIVE DRAWING] FIG. 1

FIG. 1



attitude detection sensor
1
tilt sensing part 2a
21
22
220
25
23
24
28
IC substrate
10
10b
10a
10c
Z
Y
X
12
14
41 magnetic sensing part
42 magnetic sensing part
43 magnetic sensing part
44
45
tilt sensing part 2b

FIG. 2

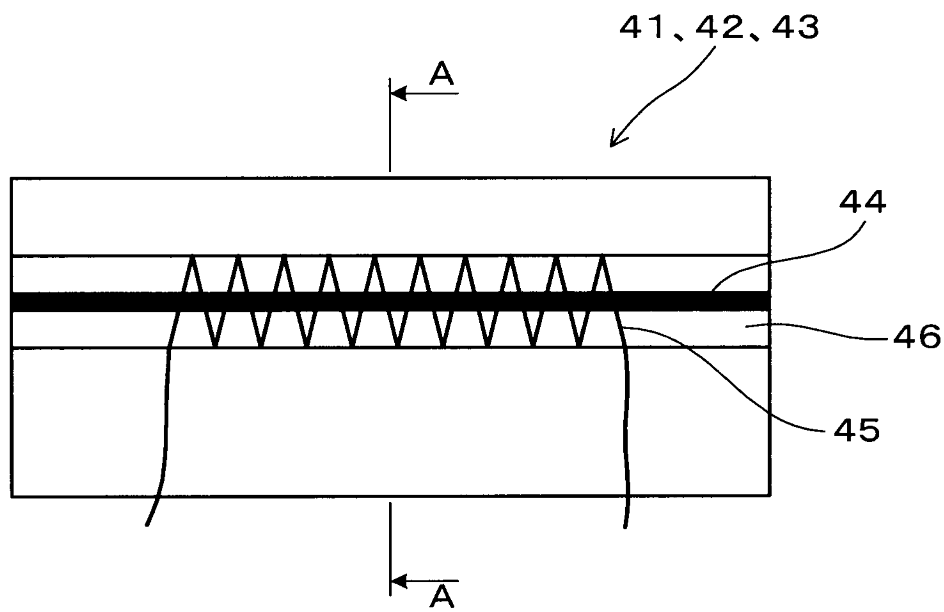


FIG. 3

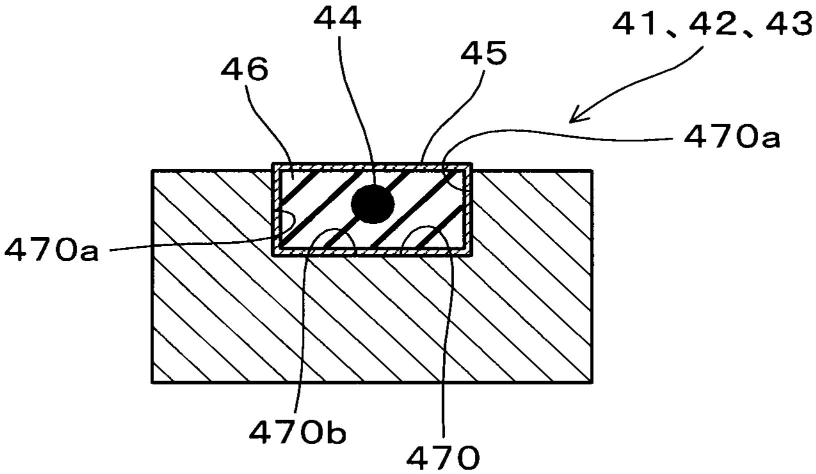


FIG. 4

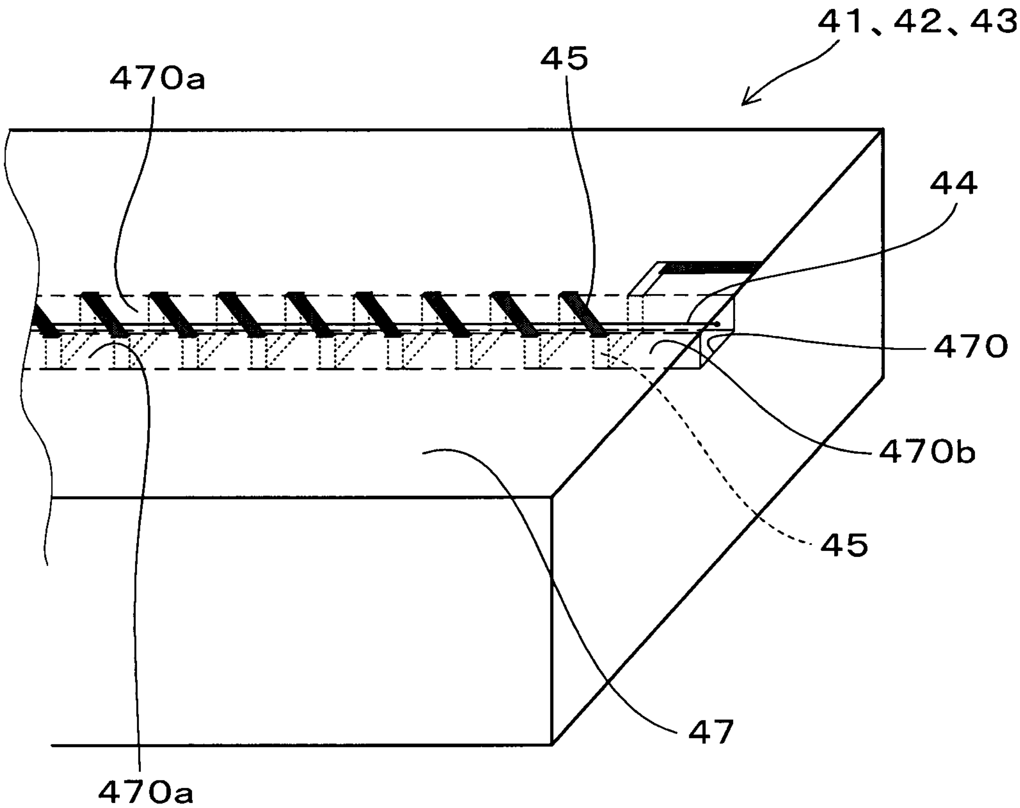


FIG. 5

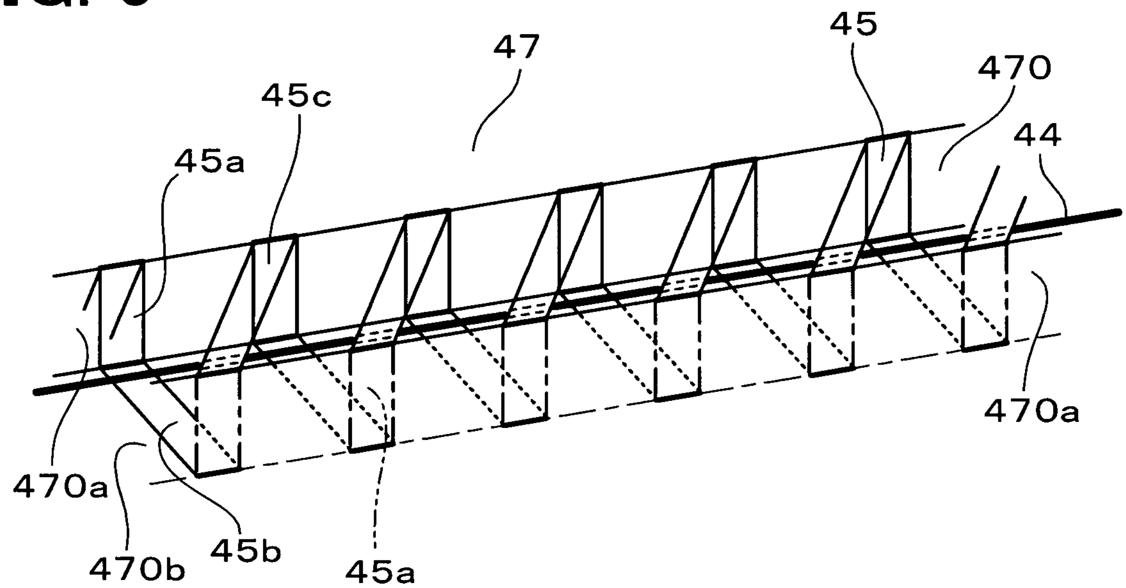


FIG. 6

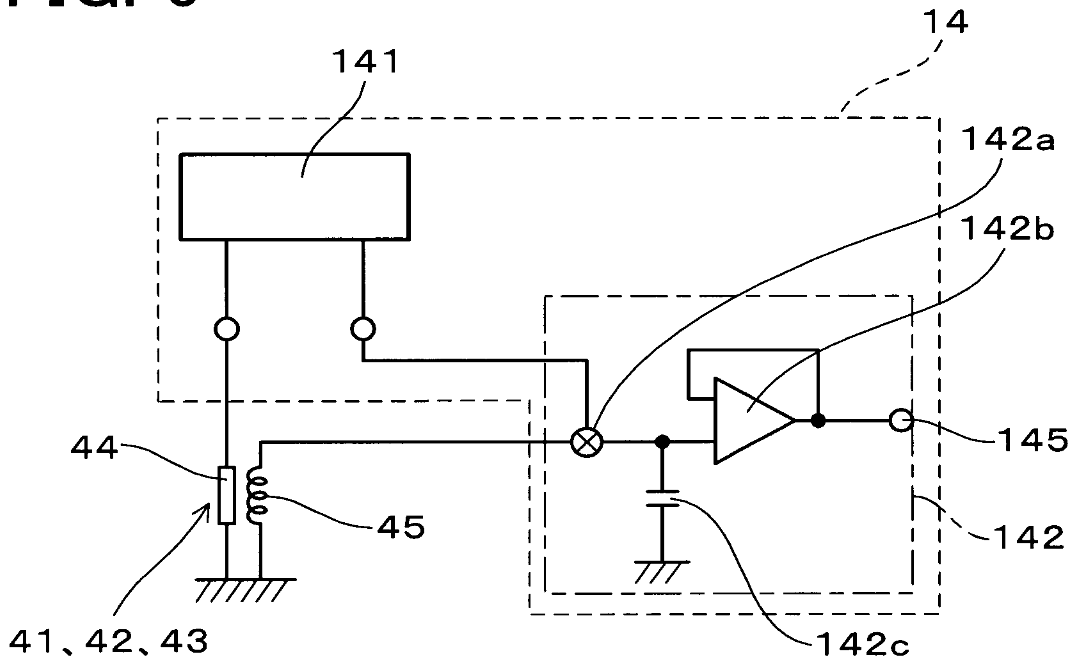
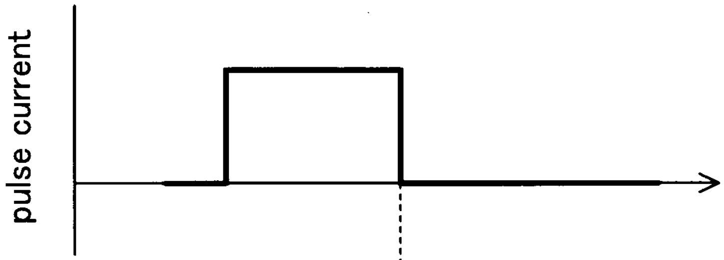


FIG. 7

(a)



(b)

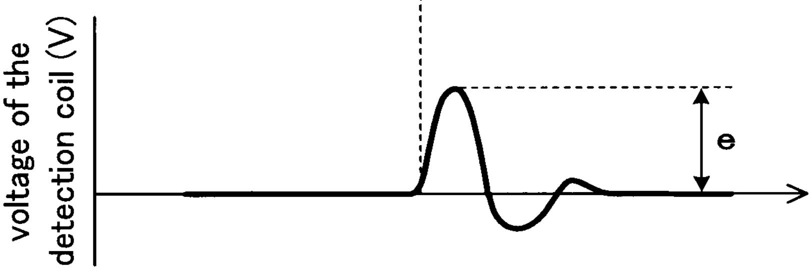


FIG. 8

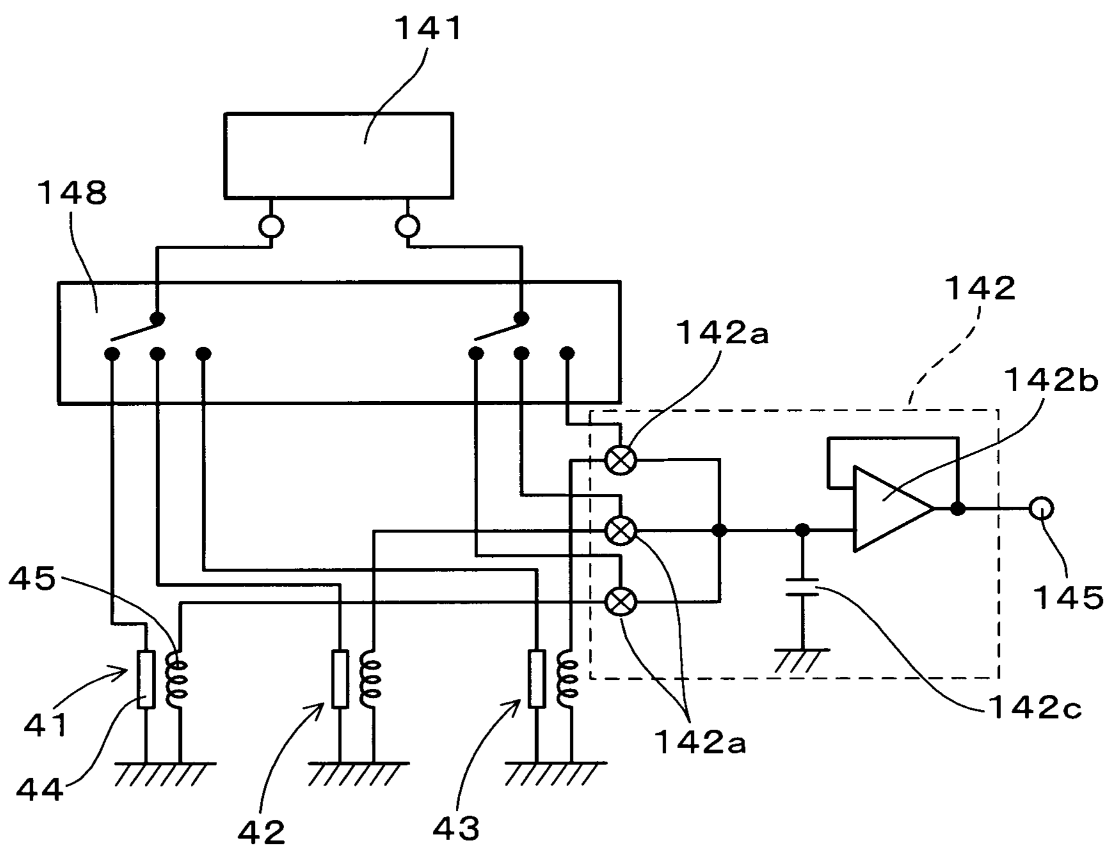


FIG. 9

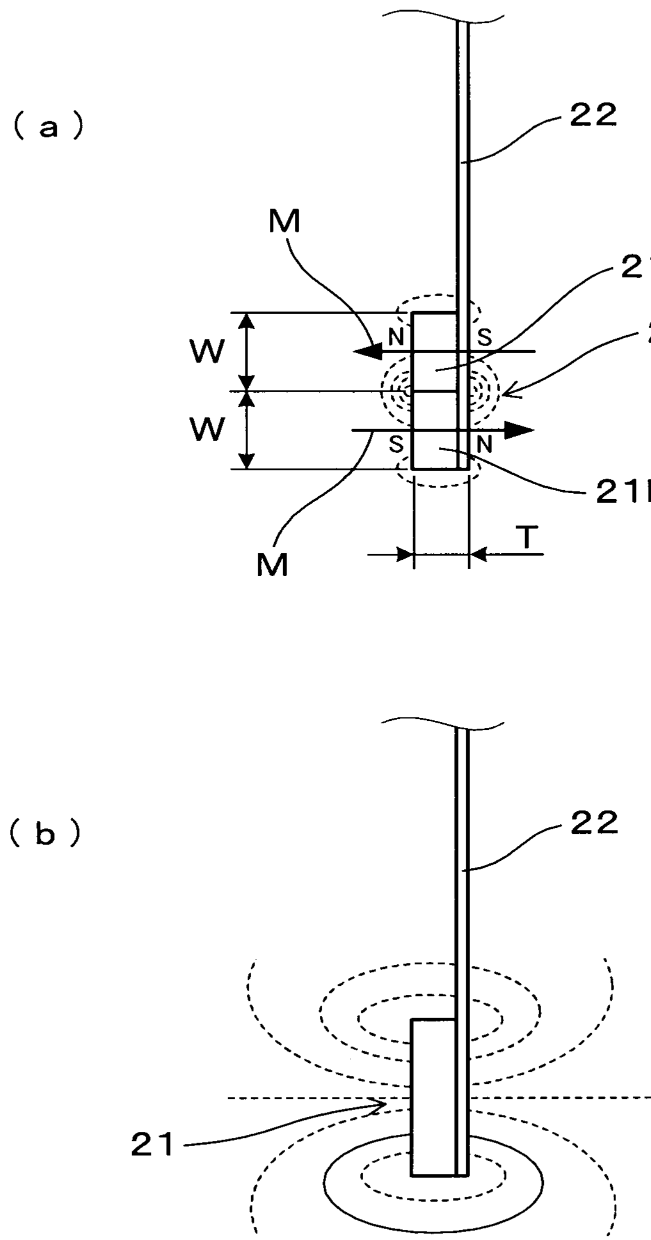


FIG. 10

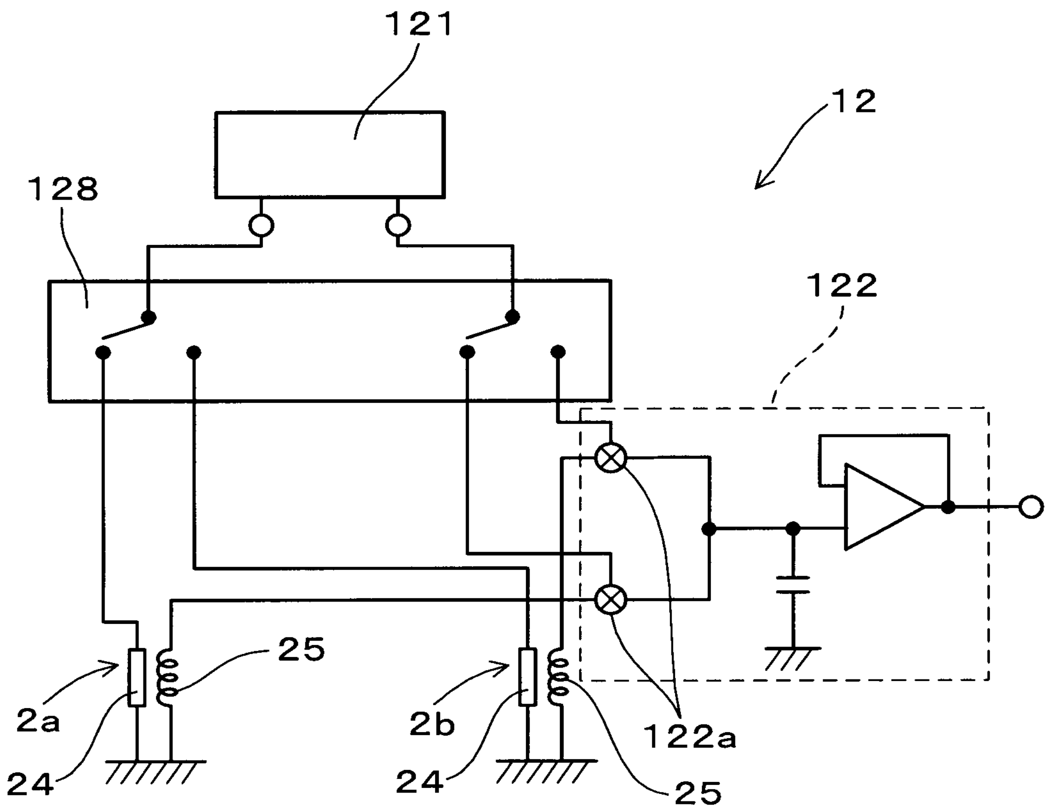


FIG. 11

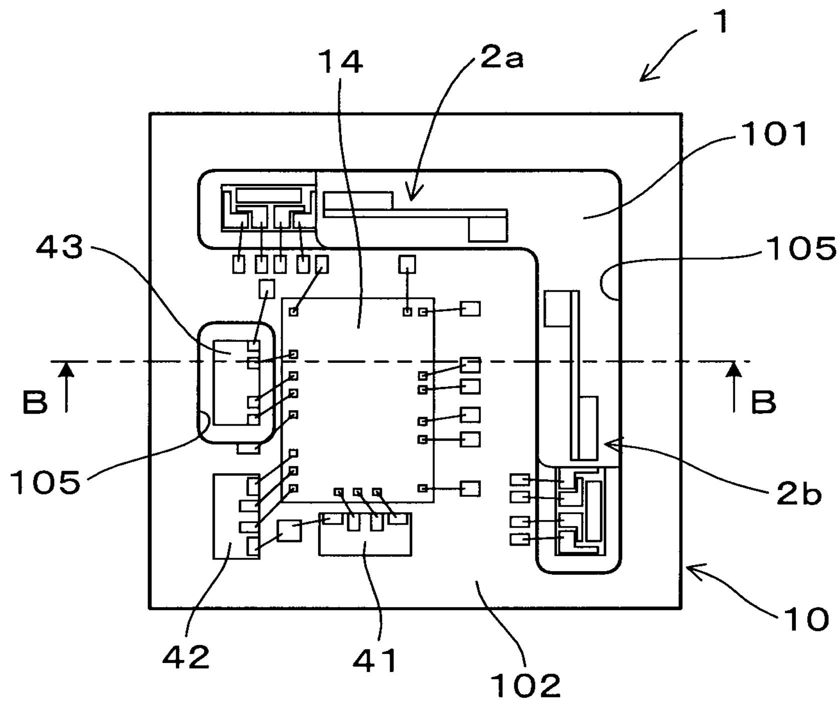


FIG. 12

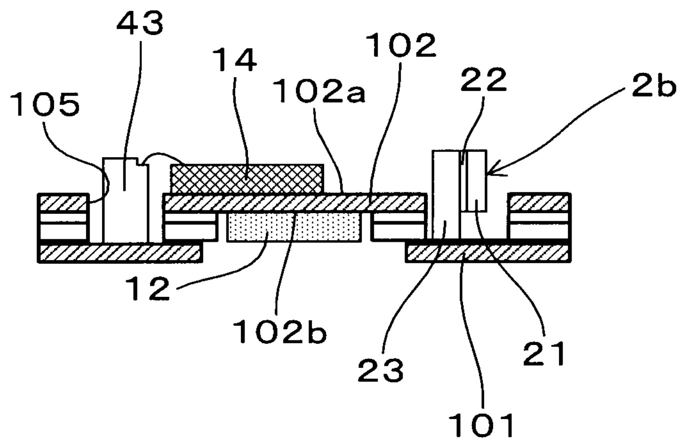


FIG. 13